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GRAHAM BELL'S TETRAHEDRAL KITES.

FROM THE SMITHSONIAN REPORT FOR 1903, PAGES 183–185 (WITH PLATE I).

(No. 1496.)

WASHINGTON: GOVERNMENT PRINTING OFFICE.

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a Reprinted from Nature, London, August 13, 1903, No. 1763, vol. 68, pp. 347–349.

In the June number of the National Geographic Magazine (Washington, D. C.) is a very interesting and instructive article by Dr. Graham Bell on the tetrahedral principle in kite structure. The article itself is so concise and depends so much upon illustrations, which are reproduced to the number of 20 in the text and 70 in the Appendix, that an effective representation of the contents in an article of smaller dimensions is scarcely possible.

Still the line of thought that runs through the work which the article represents is so clear and so suggestive that even an imperfect outline of it may be useful. Doctor Bell indicates certain states in the development of his ideas as "milestones" of progress, and since the ultimate stage of the development is the possibility of building up very large kite structures by combining unit cells in such a way that the proportion of weight to wing area in the structure is nearly the same as that of the constituent cell the successive stages are noteworthy. They sketch out in a most interesting manner a reply to Newcomb's criticism of the limits of application of the aeroplane based upon the argument that increase of size means diminished efficiency because, for similar structures, the weight varies as the cube, while the area, upon which the lifting force depends, varies as the square of the linear dimensions.

The original stage, the ordinary kite, is a single plane structure. The first step in advance is the Hargrave box kite, with its upper and lower aeroplanes for its support and side planes for stability. To stiffen the framework of the box kite it must be braced longitudinally and transversely. Accordingly Graham Bell's development commences by replacing the rectangular framework of the box kite by a framework of triangular section, which is by construction stiff so far as the cross section is concerned. The inclined sides are by the vector principle of resolution of forces regarded as equivalent to their geometrical projections, and, in so far as the principle applies, the inclined 184 faces represent the combined effect of aeroplanes of the area of the projections.a

a This principle to be generally applicable would require the normal component of wind pressure to be uniform and independent of the angle between the plane and the wind. This is not the case with an aeroplane (see Rayleigh, Nature, vol. XXV, p.108); and for the principle to be applied approximately in the case of the kites some convention as regards the angle of exposure of the aeroplanes to the wind would be required.

The box kite of triangular section is, however, not stiff as regards longitudinal shear, and the next "milestone" marks the reduction of the triangular or prismatic form to the

tetrahedron, an essentially stiff framework for all directions. A tetrahedron of rods with two adjacent faces covered with fabric forms a tetrahedral kite cell which, on the principle of projection before referred to, is equivalent to three aeroplanes represented by the projections of the covered sides upon planes at right angles.

The further development of pure tetrahedral construction is obvious. Four cells can be combined to form a tetrahedron of double linear dimensions without additional framework; the weight and wing area are both simply proportional to the number of cells, and not to the linear dimensions. For each set of four cells thus combined there is an octahedral free space in the interior which corresponds to the free space between the two cells of the Hargrave kite. The tetrahedral kites that have the largest central spaces preserve their equilibrium best in the air.

Combining 4 multiple cells to fill the outline of a tetrahedron of double size, again, we get a 16-cell kite, and repeating the process again a 64-cell kite, occupying a tetrahedron eight times the dimensions of a single cell. The building up of multicellular kites from the units is represented in the figures here reproduced from illustrations in Doctor Bell's article. Fig. 1, Pl. I, represents the unit cell; fig. 2 a combination of 4 cells; fig. 3 of 64 cells.

The kites fly with the points of the wings upward; the line of junction of the covered faces of the tetrahedron forms a kind of keel. No details as to the heights attainable are given. The most convenient place for the attachment of the flying end is said to be the extreme point of the bow. If the cord is attached to points successively farther back on the keel, the flying end makes a greater and greater angle with the horizon, and the kite flies more nearly overhead; but it is not advisable to carry the point of attachment as far back as the middle of the keel. A good place for high flights is a point halfway between the bow and the middle of the keel.

"Tetrahedral kites combine in a marked degree the qualities of strength, lightness, and steady flight; but further experiments are required before deciding that this form is the

best for a kite or that 185 winged cells without horizontal aeroplanes constitute the best arrangement of aero-surfaces.

"The tetrahedral principle enables us to construct out of light materials solid frameworks of almost any desired form, and the resulting structures are admirably adapted for the support of aero-surfaces of any desired kind, size, or shape."

The diagrams illustrating the article show various examples of the formation of complex kites from tetrahedral cells. One form suggested by Professor Langley's aerodrome, but different in construction and appearance, is shown in fig. 4, reproduced from an illustration in the article. That some of these complex kites are on a very large scale is evident from a case cited, in which an aerodrome kite, which was struck by a squall before it was let go, lifted two men off their feet, and subsequently broke its flying cord, a Manila rope of three-eighths inch diameter.

The simplicity of the construction of the cells, and the obvious possibilities of their combination, lend an additional fascination to a subject which is already full of interest.